Muon Collider Power Consumption

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FNAL Mini-Workshop
5/19/11

- Cryo efficiency
- Front end examples
- Summary of Power Requirements
- 1998 discussion
- Options
- Conclusions

Cryogenic Efficiency

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SC-MAG-341

ESTIMATING THE COST OF SUPERCONDUCTING MAGNETS AND THE REFRIGERATORS NEEDED TO KEEP THEM COLD*

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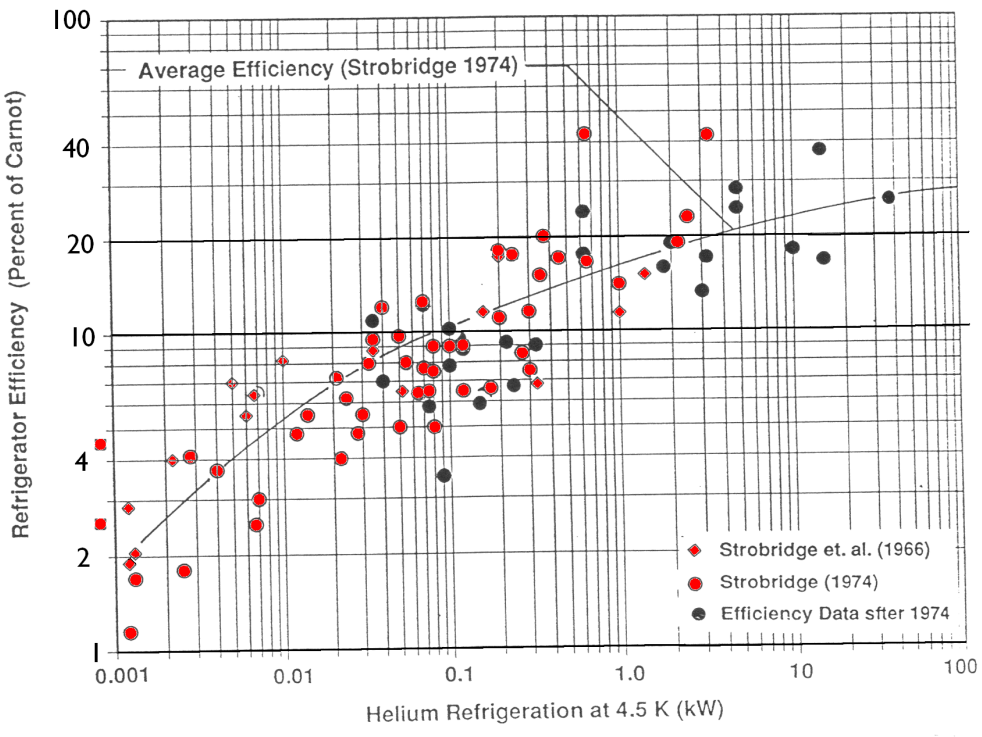
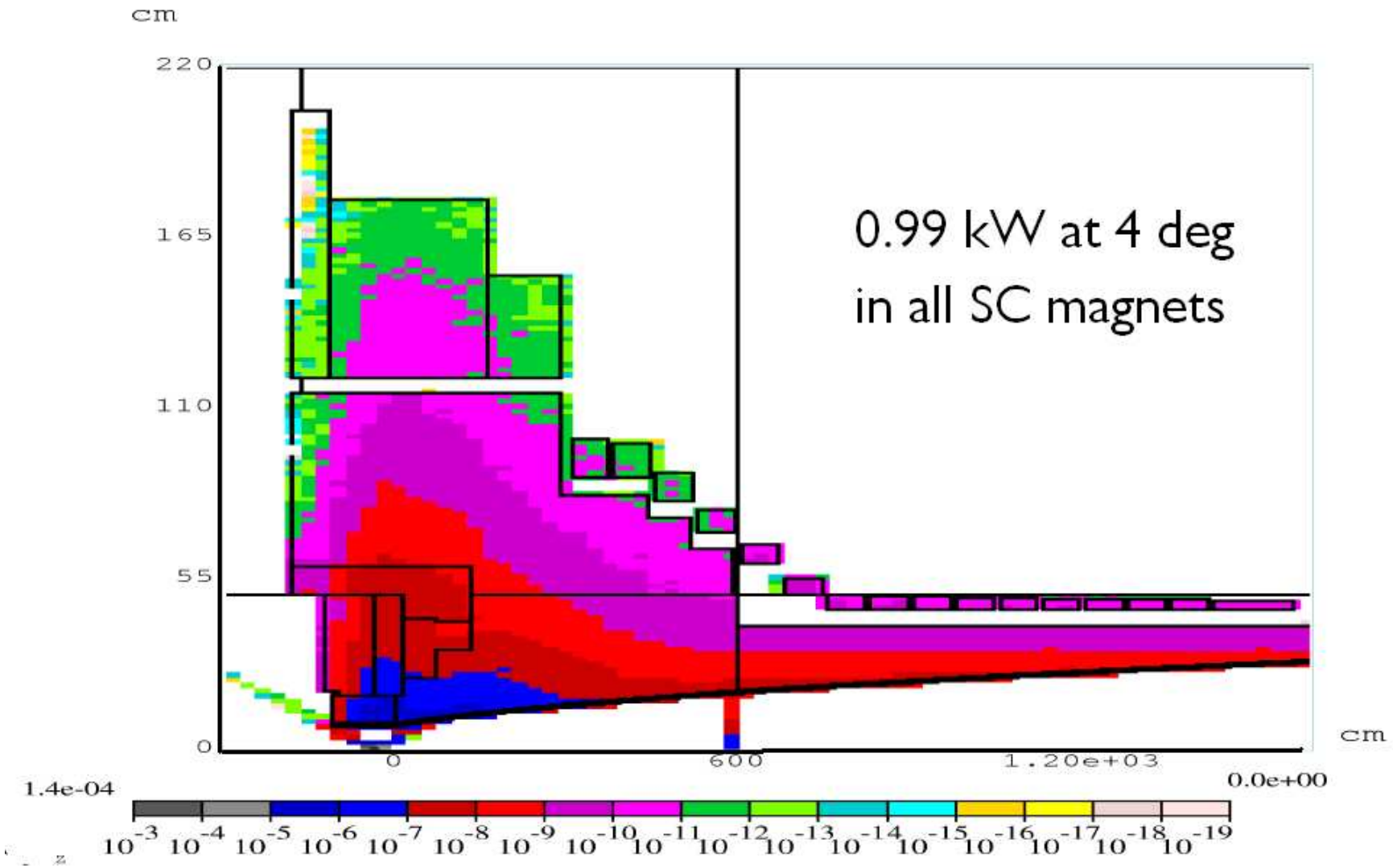


Figure 3. The Efficiency of Helium Refrigerators as a Function of 4.5 K Refrigeration

- Efficiency $\approx$ 20% of Carnot
- for 4 deg: $0.2 \times 4/300 \approx 1/375$
- for 70 deg: $0.2 \times 70/300 \approx 1/21$

Target and Capture

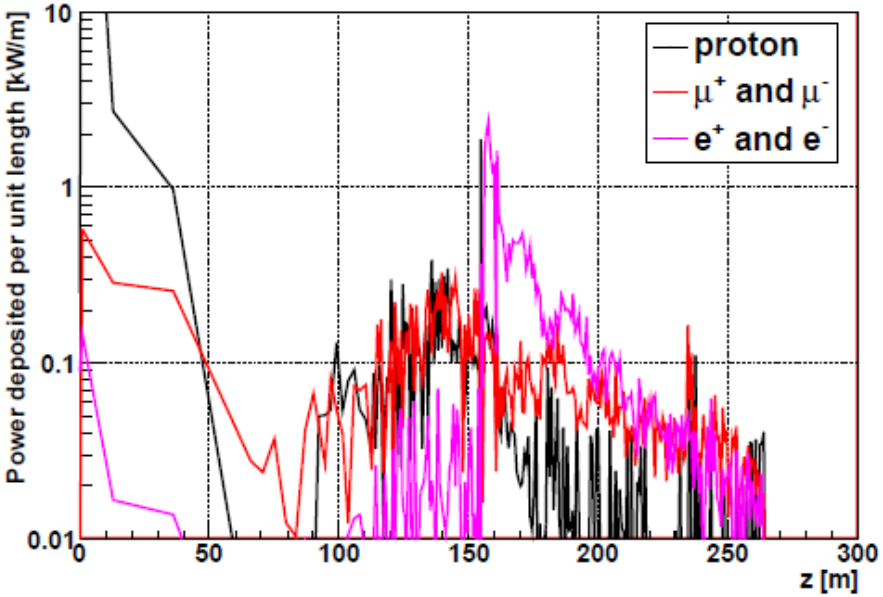
Harold Kirk and Nicholas Souchlas

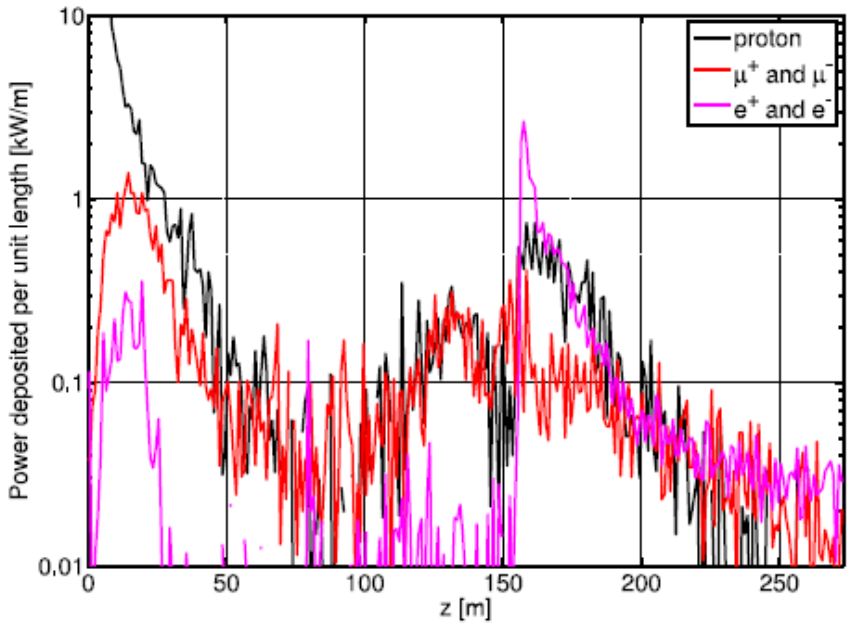


Front End Losses

- Significant differences between G4beamline and ICOOL
- Neither had any shielding

- Approximate losses
  - Phase rotation: 12 kW $\longrightarrow$ 4.5 MW
  - Cooling 18 kW $\longrightarrow$ 6.8 MW





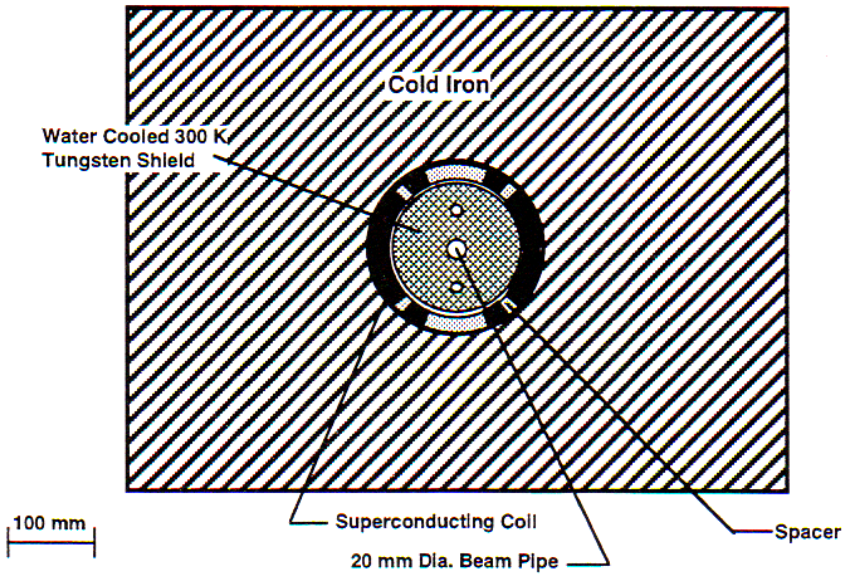
Wall power consumptions

	Len	P_{peak}	Static	Dynamic	—	—	—	—	Tot
			4^o	rf	PS	4^o	20^o	70^o	
	m	MW	MW	MW	MW	MW	MW	MW	MW
p Driver (SC linac)									(20)
Target and taper	16				10.0	0.4			10.4
Decay and phase rot	95	220	0.1	0.8		4.5			5.4
Charge separation	14								
6D cooling before merge	222	1420	0.6	7.2		6.8	6.1		20.7
Merge	115	10	0.2	1.4					1.6
6D cooling after merge	428	1350	0.7	2.8			2.6		6.1
Final 4D cooling	78		0.1	1.5			0.1		1.7
NC RF acceleration	104	35	0.1	4.1					4.2
SC RF linac	140	50	0.1	3.4					3.5
SC RF RLAs	10400	570	9.1	19.5					28.6
SC RF RCSs	12566	790	11.3	11.8					23.1
Collider ring	2600		2.3		3.0	(5)		(5)	15.3
Totals	26777	4445	24.6	52.5	13.0	16.7	8.8	5	140.6

- Allow 5 MW (wall) $\rightarrow$ 13 kW (4 deg) plus 240 kW at 70 deg.
- beam power 9 MW 3 MW to electrons Max leakage to 4 deg 0.43 %

From 1998 Feasibility Study

Cos theta



- Most radiation in horizontal plane
- Shielding and magnet could be ellipti
- At 2 TeV almost equal in & out

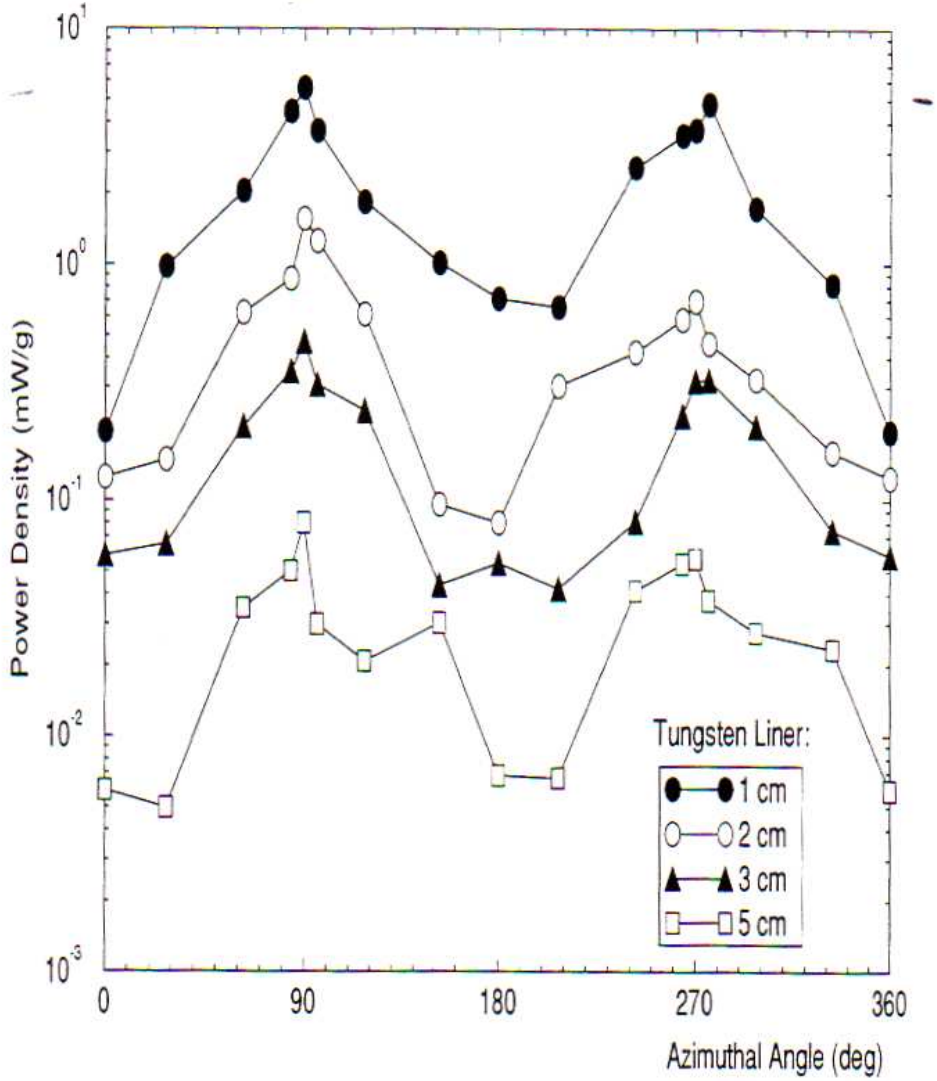
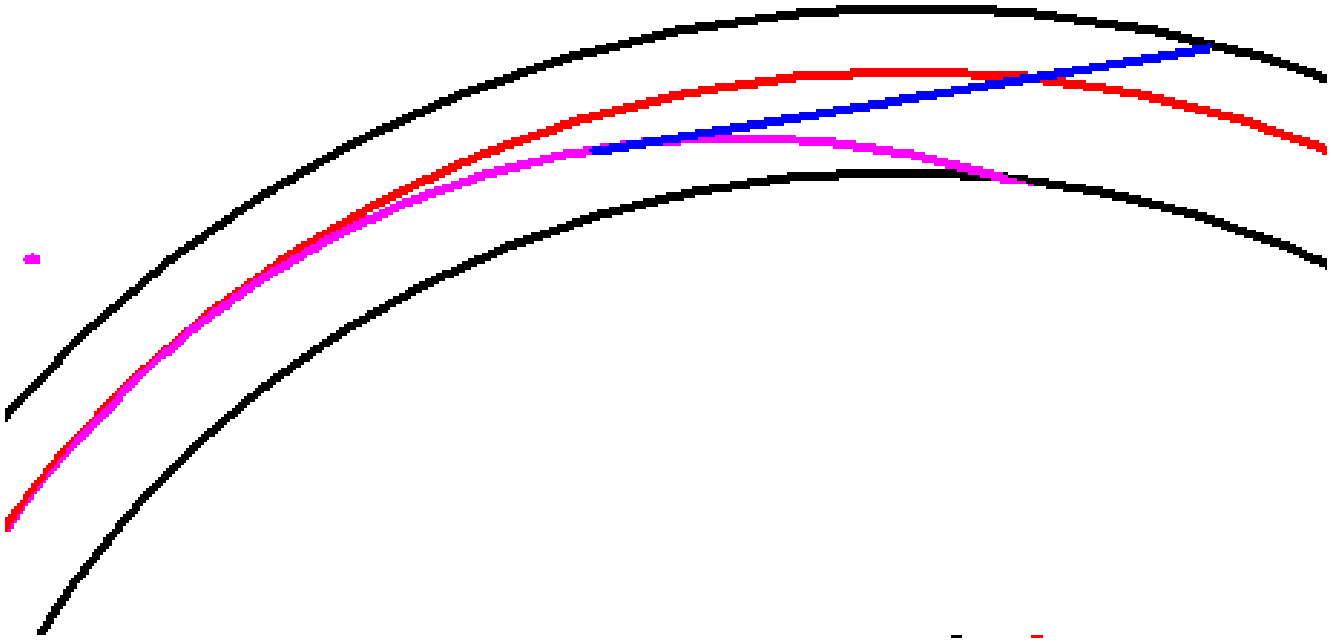


Figure 8.14: Azimuthal distribution of power density in the first SC cable shell in the collider arc for different tungsten liners inside the aperture for 2 TeV muon beam decays

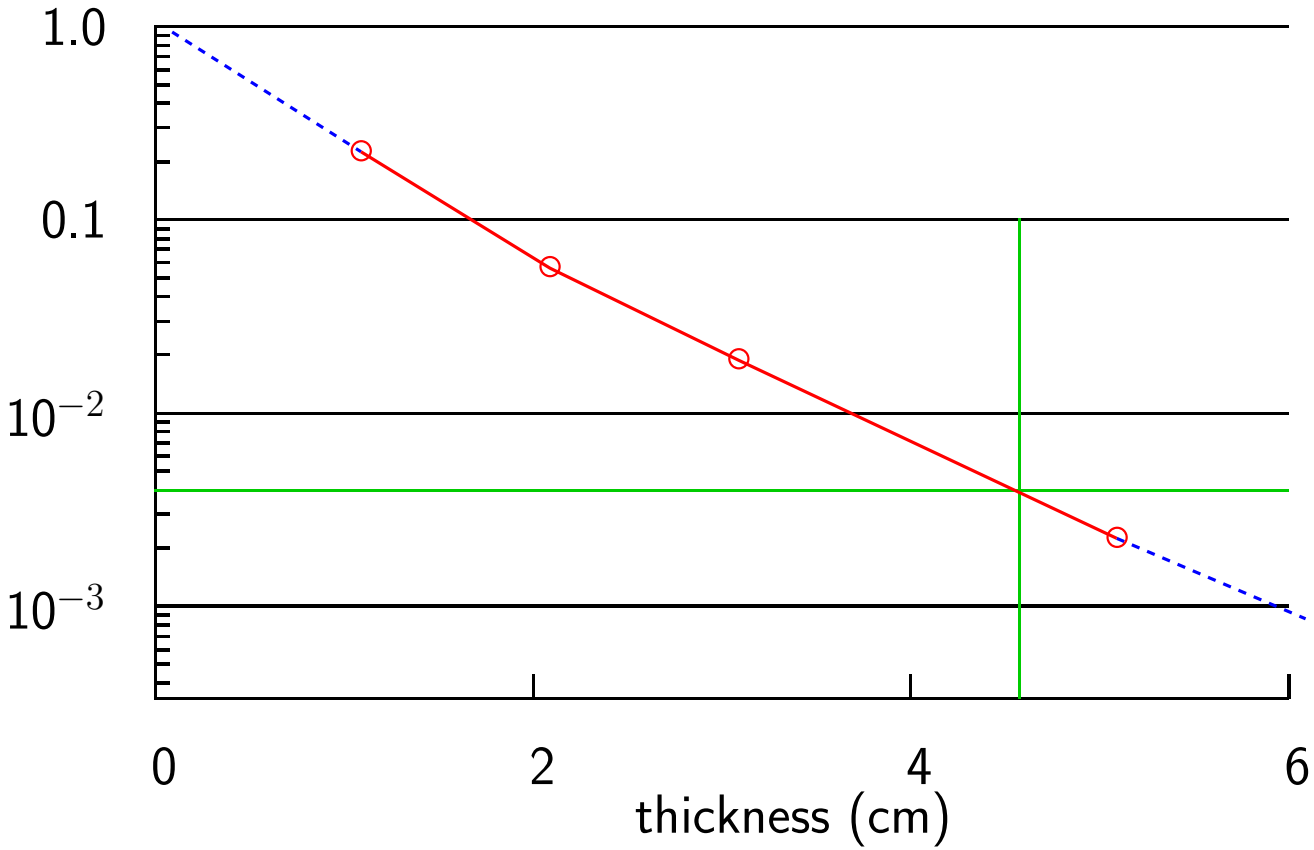
Why both in and out?



- Magenta electron spirals in
- Blue radiation crosses to outside
- At low energies there is less of this radiation

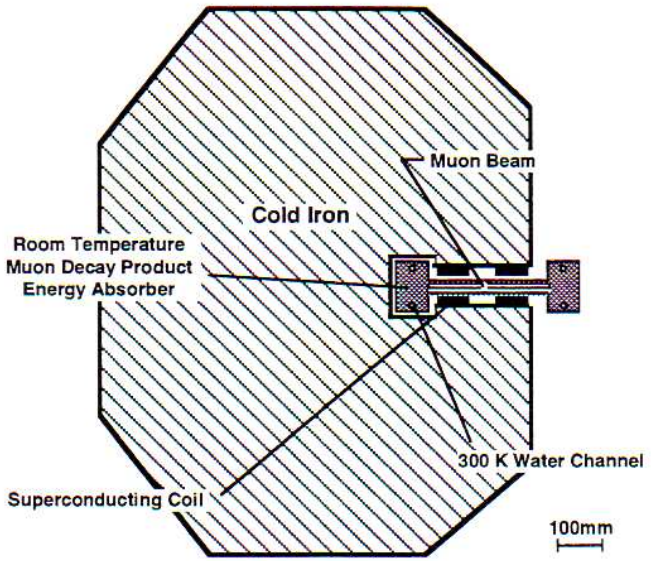
Required thickness of tungsten

- Beam power 9 MW
- Power to electrons 3 MW
- Required thickness for 0.43% leakage 4.6 cm

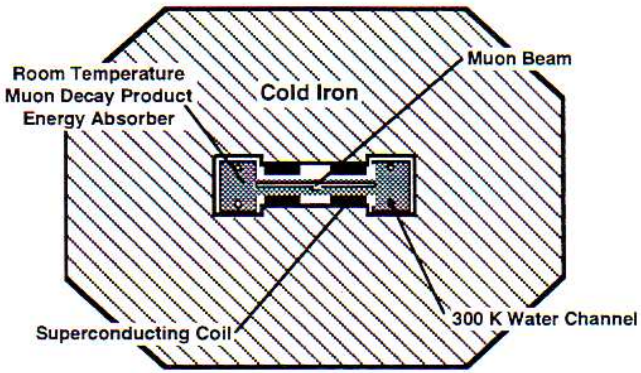


Open Mid-pl

- Already discussed in 1998



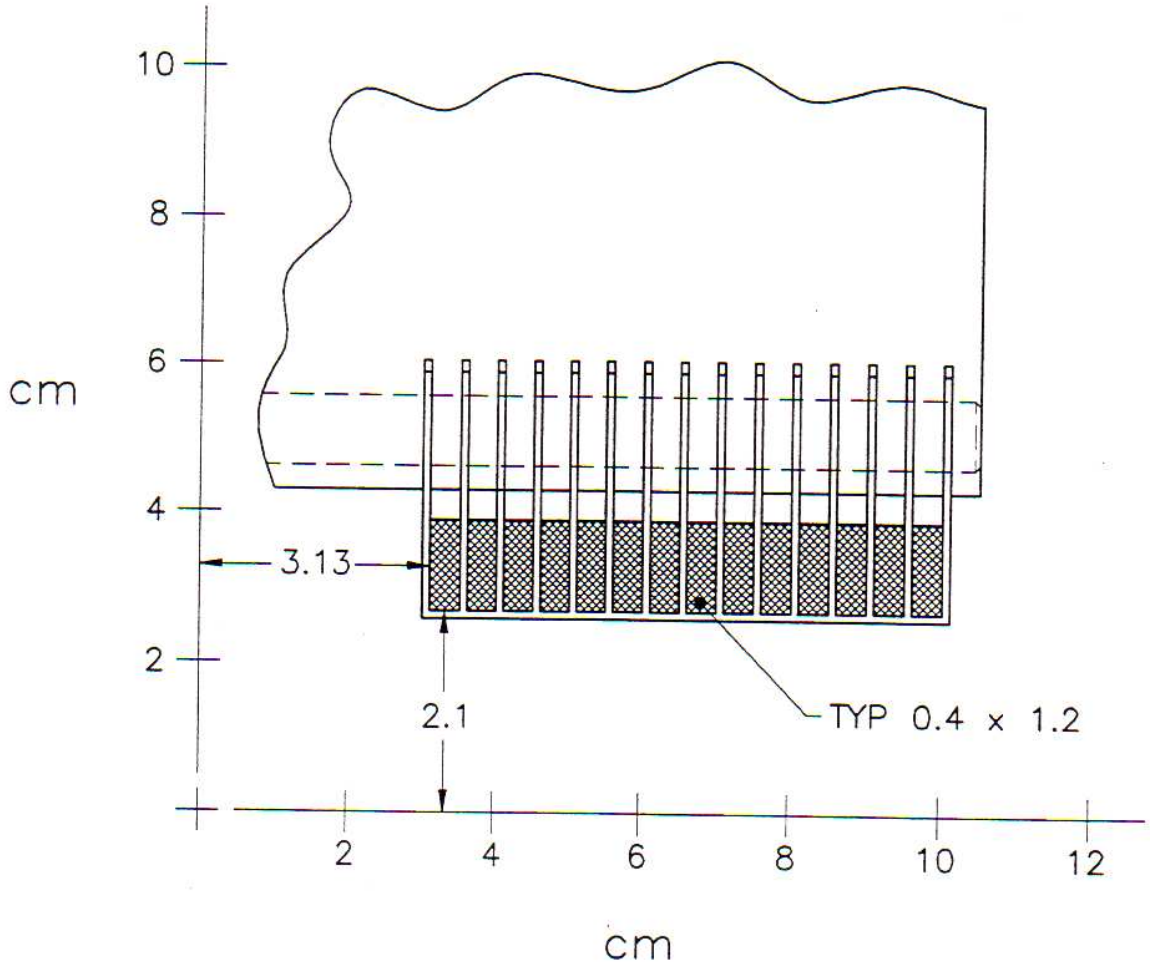
a) Cold Iron C Dipole Magnet



b) Cold Iron H Dipole Magnet

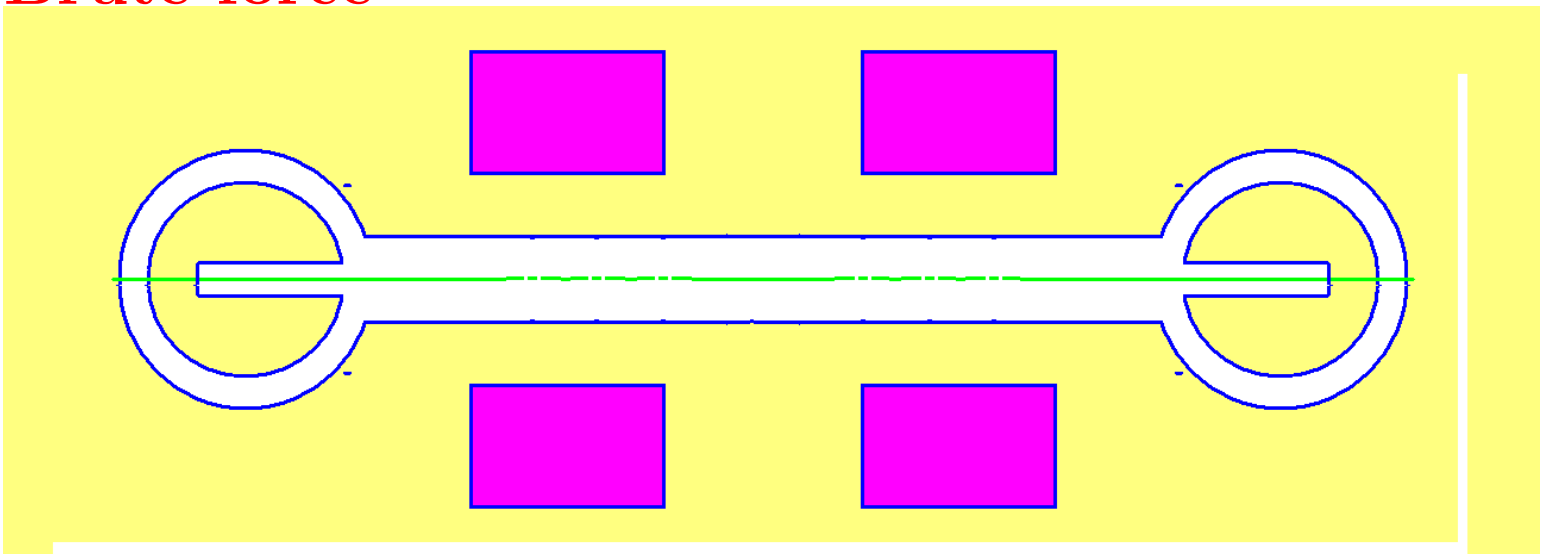
Figure 8.12: Two versions of an 8.5 T cold iron split dipole that would have less than 0.1% of the muon decay power deposited within the superconducting coils

98 idea for "hanging coils"

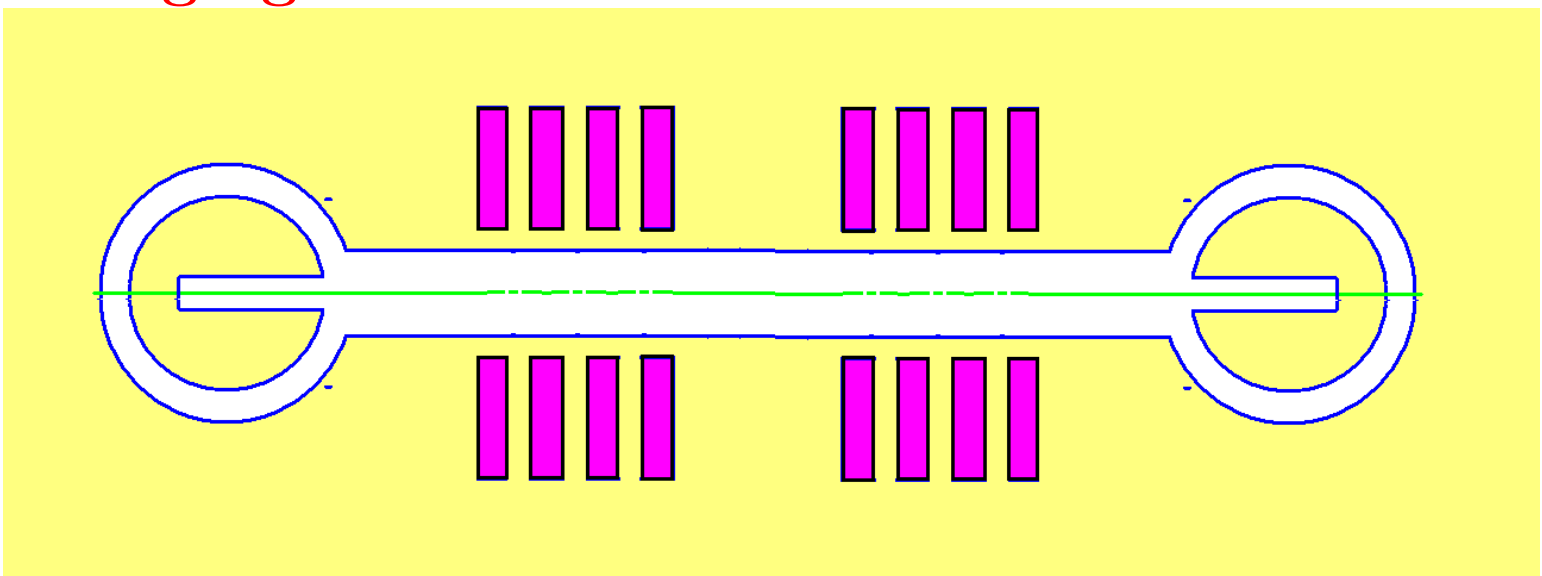


Options

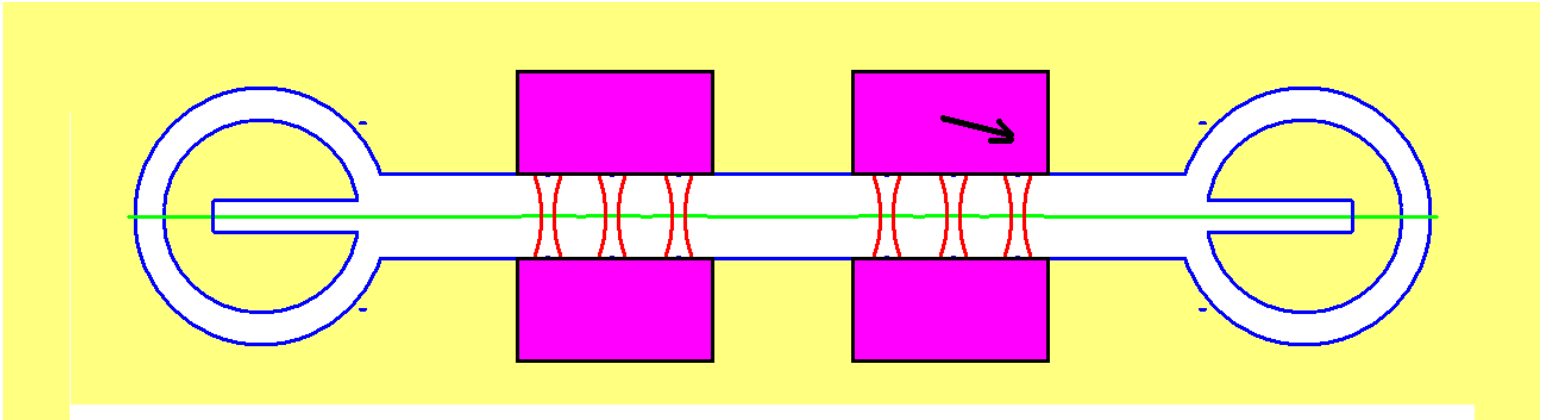
Brute force



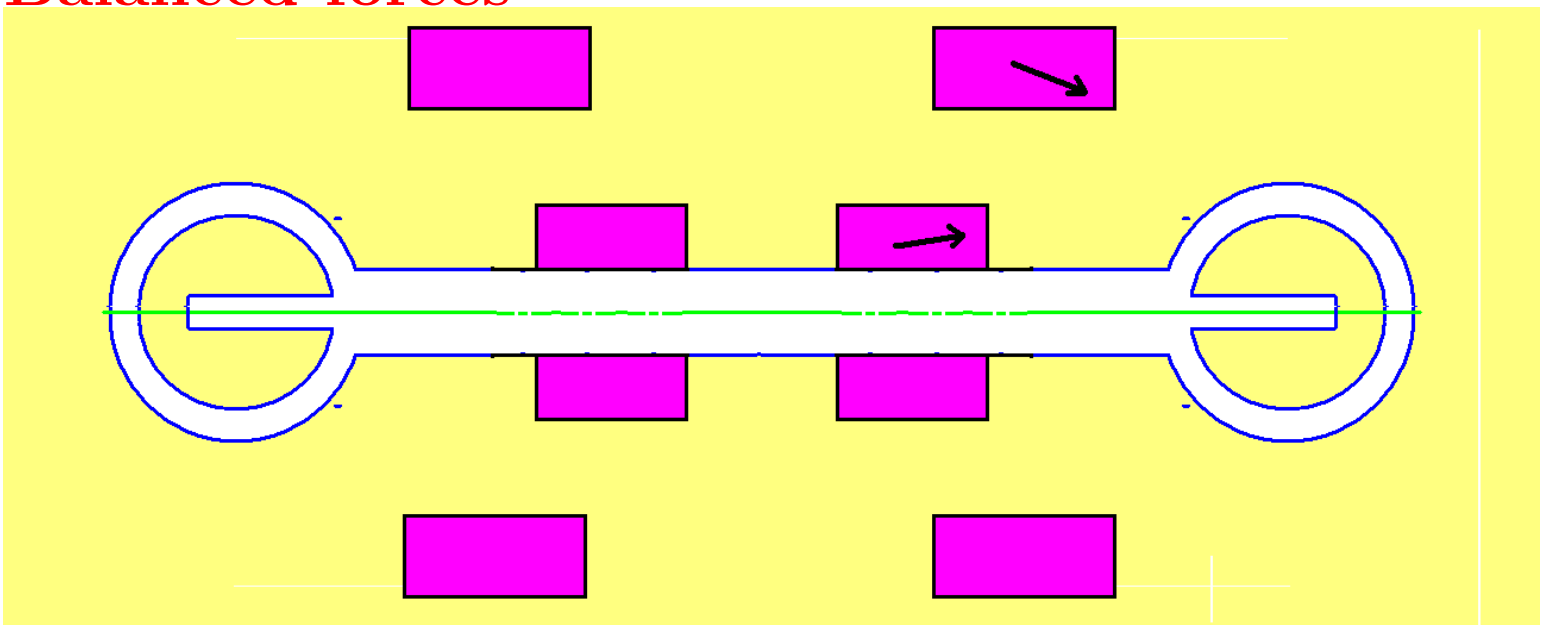
"hanging coils"



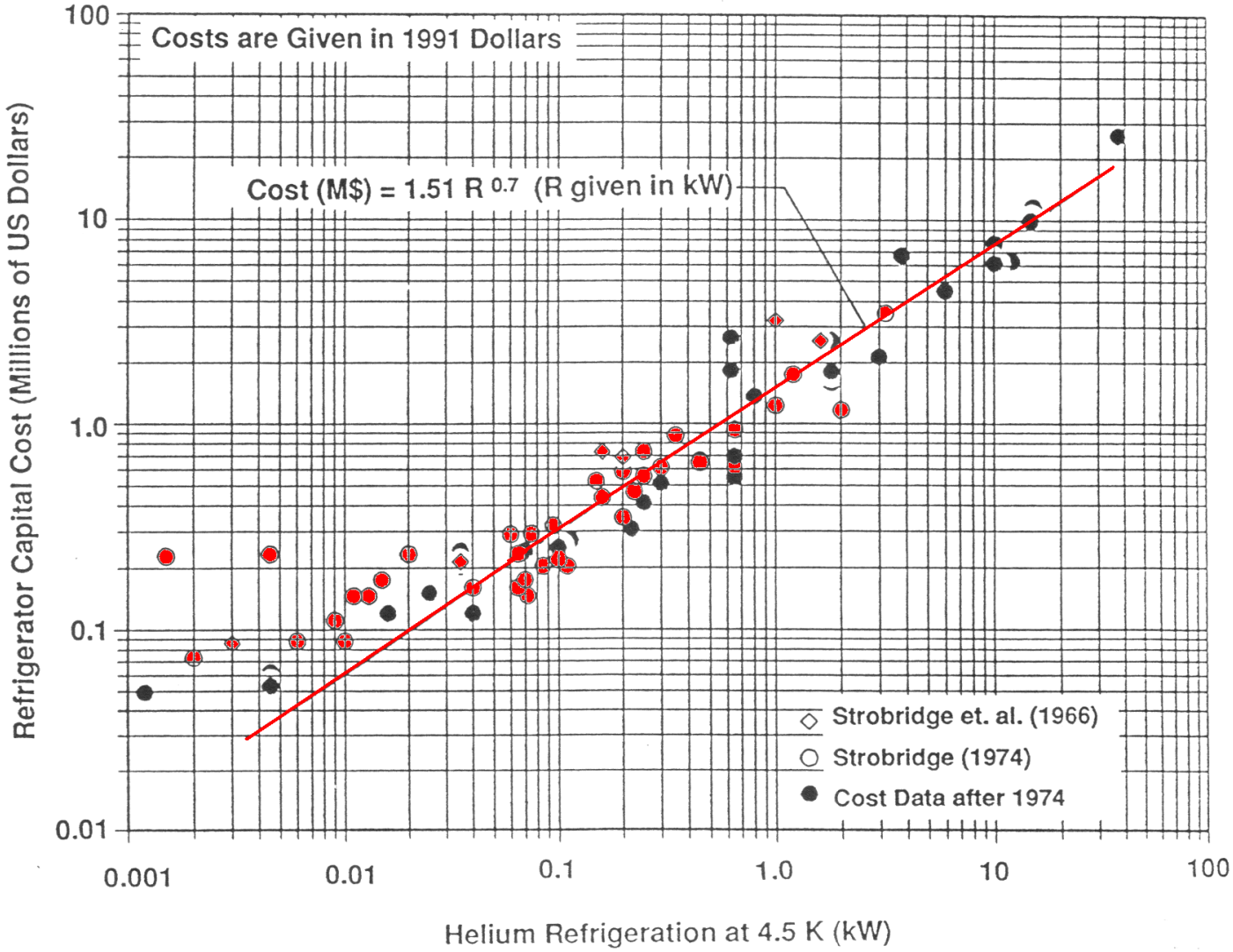
Be supports



Balanced forces



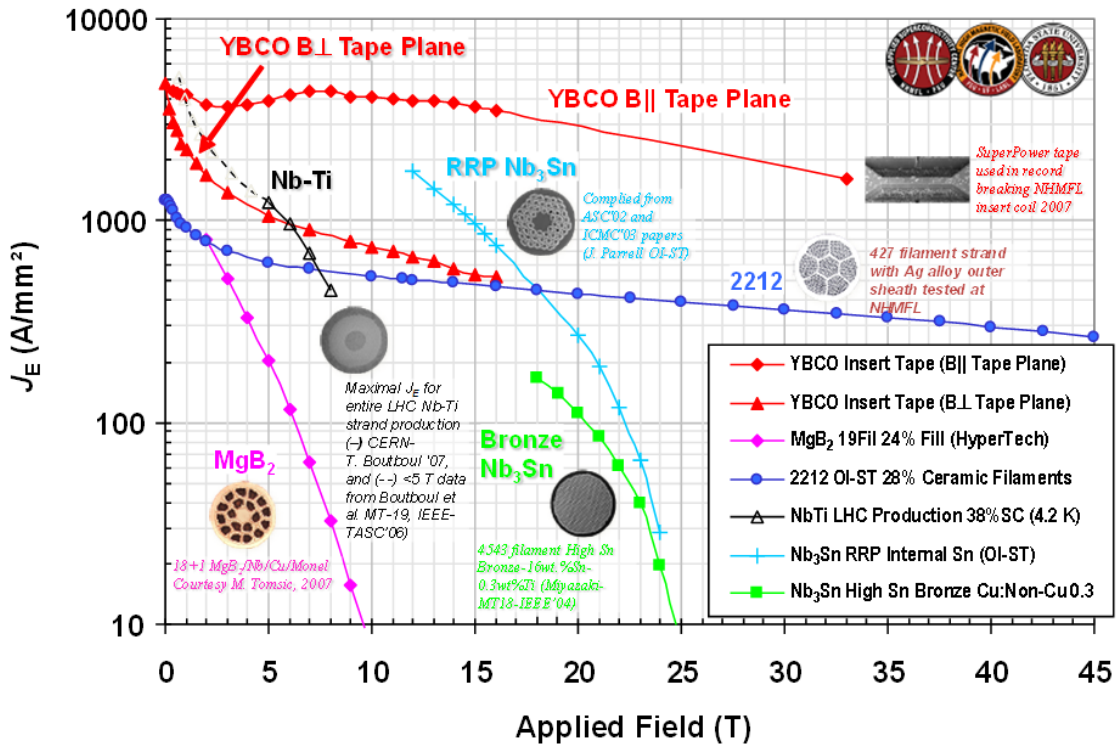
Cost of refrigeration



For 13 kW in 2011 \$s Cost $\approx$ 25 M\$

Choice of Field

- In p colliders increased field saves real-estate but does not effect performance
- But for Muon Collider: Luminosity/Radiation $\propto 1/B$
- Choice of 10 T based on current thinking
- Possibilities of 15 - 20 T should not be ignored
- j vs B suggests HTS not needed for B<19 T
- But lack of training could make HTS more attractive



Conclusion

- 3 MW of 9 MW muon beam goes to electrons
- To avoid unreasonable power use (eg 5 MW)
- Losses to 4 degrees should be less than 13 kW
- A tungsten liner 4.6 cm thick would do this, but coil bore now 11-12 cm diameter
- Open mid-plane dipoles look very attractive if possible
- Several ideas
  - Brute force
  - Hanging coils
  - Be supports
  - Balanced forces
- 15-20 T worth thinking about